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ABSTRACT

More than two decades of research and experience supports the idea that computer and calculator technologies can have an important role to play in supporting and effecting student learning (Heid, 1988; Kaput, 1992; Kutzler, 1996; Papert, 1980; Waits and Demana, 1999). The development of Classroom Communication Systems (CCSs) is providing new possibilities for technologies to play a fundamental role in creating and supporting effective learning environments. The TI-Navigator from Texas Instruments (TI) is a wireless CCS and its advent brings the power and potential of CCSs into K-12 classrooms in a novel, flexible, and mobile way. The pedagogical potential of CCS technology is still in its development stage but preliminary research suggests considerable benefits to active student participation in class and collaborative inquiry in the classroom (Abrahamson, Davidian, & Lippai, 2000; Bransford, Brophy, & Williams, 2000; Davis, 2002; Dufresne, Gerace, Leonard, Mestre, & Wenk, 1996; Mestre, Gerace, Dufresne, & Leonard, 1997; Wenk, Dufresne, Gerace, Leonard, & Mestre, 1997). The present study is designed to illustrate the potential of CCSs in facilitating effective teaching and creating effective learning environments. (Author)

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PREPARING PROSPECTIVE ELEMENTARY TEACHERS TO FOSTER CONCEPTUALLY BASED MATHEMATICAL UNDERSTANDINGS: A STUDY INVESTIGATING CHANGE IN PROSPECTIVE TEACHERS' CONCEPTIONS RELATED TO MATHEMATICS TEACHING AND LEARNING

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This study reports first year findings from a multi-year research project that examines changes in prospective elementary teachers' conceptions related to conceptually based mathematics teaching and learning. This study is the result of a *design experiment* (Brown, 1992) advanced between traditionally distinct departments of mathematics and education in a large, state-supported university. Participants include 300 elementary education students during mathematics content and general pedagogy courses. Results suggest that most prospective teachers changed their conceptions of mathematics and its teaching and learning during this program. Specifically, changes were made in two areas: appreciation of role of content knowledge in designing and implementing instruction, and perception of mathematics as more than rules to be memorized.

This research paper reports first year findings from a multi-year (2001-2004) study that examines changes in prospective elementary teachers' conceptions related to conceptually based mathematics teaching and learning. This study is the result of a *design experiment* (Brown, 1992) advanced between traditionally distinct departments of mathematics and education. Our efforts respond to a current dilemma in teacher education. Students often leave teacher education programs with the same preconceived notions about content, teaching and learning as when they enter (Ball, 1988; Murphy, 1990). One contributing factor is that many teacher education programs, particularly at the elementary level and in mathematics, do not connect across content and method throughout the entire program (Ishler, Edens, & Berry, 1996). Although students traditionally take courses in mathematics, general pedagogy and mathematics education, these courses often do not stress conceptual understanding of content. Many programs do not make conceptual understandings explicit enough to challenge previous conceptions of mathematics, nor do they place these new understandings within the larger context of teaching (e.g., Borko et al., 1993).

Our designed program seeks to assist prospective teachers in developing an orientation that promotes conceptually based mathematics instruction. We are defining "orientation" to include a teacher's knowledge, beliefs, and understandings about mathematics and mathematics teaching which frame his/her thinking and decision-

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making as it relates to practice (Magnusson, Palincsar, Marano, Ford & Brown, 1999). To this aim this study investigates the following questions: (1) WHAT changes occur in prospective elementary teachers' orientations toward mathematics and its teaching and learning?, and (2) HOW can an integrated program that promotes conceptually based understanding facilitate change in prospective teachers' orientations?

This paper examines findings related to the first research question.

Theoretical Framework

This study draws on areas of research in mathematics teacher education related to teacher orientation and teacher change. Prospective teachers struggle with how to balance their mathematical anxiety and narrow mathematics orientation with their professed desire to teach in ways that reflect reform expectations (e.g., Benken & Wilson, 1996, 1998; Borko, Davinroy, Bliem, & Cumbo, 2000; Thompson, 1992; Wilson & Goldenberg, 1998). National (e.g., NCTM, 2000) recommendations call for an approach to mathematics teaching that allows students to communicate, problem solve, and engage in cooperative, conceptual mathematical activities. This shift toward more " inquiry based" instruction assumes teachers view mathematics as a tool for thought, rather than a set of rules and procedures to be memorized. However, prospective teachers' orientations are deeply embedded and difficult to change (Ball, 1990; Richardson & Anders, 1994); they are unlikely to make adjustments in their thinking without intervention and deliberate support.

Research on teacher change indicates that programs can facilitate changes in orientation within the context of educational reform (e.g., Richardson & Placier, 2001). To help prospective teachers develop their orientations the connection between content knowledge, beliefs, and pedagogical knowledge must be considered (Stipek, Givvin, Salman, & MacGyvers, 2001). Knowledge of subject matter and general pedagogy help form pedagogical content knowledge (Marks, 1990), and therefore both types of knowledge must be examined.

To develop orientations that promote teaching mathematics for conceptually based understanding, we developed a model that incorporates the relationship among three primary tenets critical to mathematics teacher education: mathematical content knowledge, pedagogical content knowledge (Magnusson, Borko, & Krajcik, 1999; Shulman, 1987) and mathematics teaching practice (Fennema & Franke, 1992) (Fig. 1). This model illustrates the important role mathematical content knowledge plays in forming one's orientation, which then serves as a lens through which pedagogical content knowledge, and later mathematics teaching practices, are developed. Our experiment addresses the connections among these elements early and jointly within the elementary education program experience. Although research has looked at one or two of these components in isolation (e.g., Brown & Borko, 1992; Hashweh, 1987; Wood, Cobb, & Yackel, 1991), few have investigated the interactions among all three (Fennema & Franke, 1992).

Orientation's Role in the Teaching of Mathematics

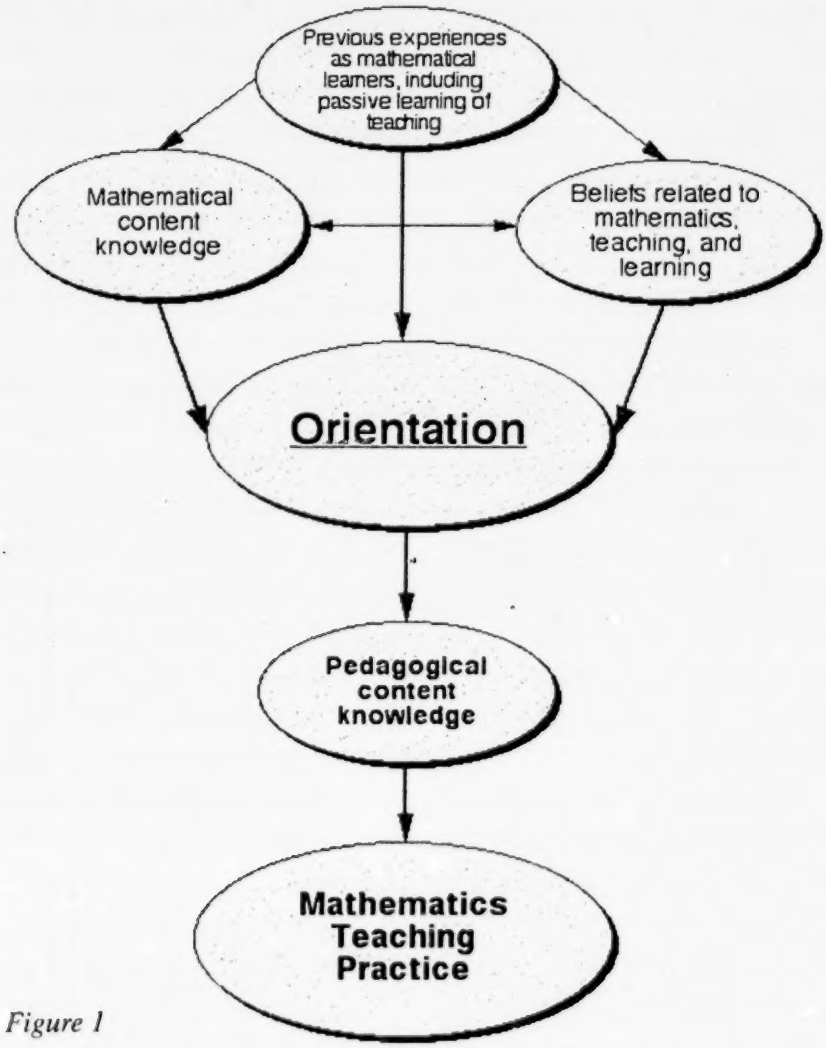
Previous experiences as mathematical learners, including passive learning of teaching
Mathematical content knowledge
Beliefs related to mathematics, teaching, and learning
Orientation
Pedagogical content knowledge
Mathematics Teaching Practice

Figure 1

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Methodology

This study takes place at a comprehensive institution serving over 14,000 students. With approximately 300 elementary education undergraduates graduating per year, the elementary education program is considered a substantial program both within the university and across the country.

Within the required elementary teacher education courses, there are three primary courses within which we are focusing our efforts related to mathematics education reform: mathematics content course, professional development course in instructional design, and mathematics methods course.

Design Experiment

The goal of our design experiment is to create an elementary mathematics teacher education program that addresses and develops students' orientations as a systemic objective. To allow time to foster new orientations we aligned previously disconnected courses in mathematical content and pedagogy throughout the required mathematics strand. Course goals reflect our common orientation toward teaching and teacher education, including active knowledge construction, opportunities for on-going reflection, focus on enduring mathematical understandings, and modeling teaching practices that support these tenants. These goals are critical in achieving teacher change (Richardson & Placier, 2001).

Data Sources

This paper examines data collected from elementary education students (n=300) during the first year (2001-2002) of a three-year research project. Project data sources include: (1) orientation surveys, (2) course artifacts, (3) content knowledge exams, and (4) semi-structured interviews. This paper explores results from surveys and course artifacts.

Orientation surveys were distributed at the beginning and end of two courses: mathematics content and general pedagogy. The content survey garners information about participants' overarching conceptions related to mathematics and its teaching. The pedagogy survey asks participants to elaborate their understanding of teaching and learning. Most survey questions (e.g., "Mathematics involves mostly facts and procedures to be learned," "It is important for teachers to have a thorough understanding of the subject he/she is teaching") use a Likert-type scale (1-5). End of course surveys also ask participants to reflect on their experiences related to specific course activities, and how these courses may have influenced mathematics orientation. Administering surveys at the beginning and end of these courses allows for interpretation of changes in individual participants' orientations and comparisons across individuals throughout the program.

Artifacts (course assignments) were collected from *experimental* sections (taught by principal researchers). Assignments were designed to allow students to make

explicit connections between being a learner of mathematics and a prospective teacher of those mathematical understandings. Assignments deliberately create cognitive conflicts (Pajares, 1993), which challenge students' conceptions, facilitate reflection, and provide opportunity for expanded thinking.

Analysis: Three Phases

(1) Data was analyzed using *direct interpretation* (Stake,1995) to garner emergent themes and patterns within individuals to understand the substantive changes in prospective teachers' thinking. Specifically, coding illustrated what changes occurred in prospective teachers' orientations toward mathematics, as well as mathematics teaching and learning.

(2) Data was *aggregated* (Stake, 1995) across individuals to understand growth in orientations across all individuals within each course.

(3) What was learned in the second phase was used to make comparisons between experimental and non-experimental sections.

In essence, case studies will be done at three levels: individual students, course section, and course design.

Validity issues are addressed by the following: (1) data is triangulated across multiple sources, (2) coding is done independently by two researchers, allowing for cross-validation of results, and (3) external validity of coding is explicit in the multi-stage nature of the research project.

Results

Preliminary results suggest that most (approximately 85%) of the prospective elementary teachers in experimental sections changed their orientations towards mathematics, as well as its teaching and learning. Specifically, changes were made in two areas: (1) appreciation of role of content knowledge in designing and implementing instruction, and (2) perception of mathematics as problem solving. In the first area, participants recognized that their own understanding of content is critical to the design and implementation of instruction. As one prospective teacher stated, "We all have different ideas about different subjects, and everything we teach will be influenced by our own understandings and beliefs about that subject." By the end of pedagogy course activities, participants also saw content knowledge as being an important attribute of a "good" teacher. This reflects a dramatic change from themes during the beginning of the course; most participants only referred to affective attributes, e.g., "caring," "kind," and "loves children." In addition to recognizing the important role of their own understanding of content in instruction, these prospective teachers also referred to their students' understanding of content as being a primary goal of instruction.

In the second area, participants changed their views of mathematics as a discipline. For example, many participants who understood mathematics as static and

comprised of rules to be memorized, later described it as complex, changing, and open-ended. By the end of the mathematics content course, almost all participants referred to mathematics as involving problem solving, using multiple approaches, and as necessary to solve problems in real-life situations. As one participant stated, "I now [after taking this course] realize there are different ways to approach problems." Changes in orientation were less evident in non-experimental sections.

Comments made by prospective teachers in end of course surveys and on course assignments indicate that the collaboratively designed activities helped to scaffold this change. For example, many participants explained that writing about their understandings forced them to reflect upon and connect those understandings. Even during the mathematics content course (often taken prior to the instruction and design course) participants commented on the need to understand content in flexible ways to best help their students understand these concepts. As one participant stated, "The more methods and strategies I learn in problem solving, the easier it will be to get concepts across to students." These findings suggest that when programs are purposely designed to understand and address students' thinking about content and pedagogy early and connectedly in a program, changes can be made in mathematical orientations that will ideally lead to conceptually based teaching.

What we find compelling related to these results is that while these prospective teachers of mathematics grew in their understanding of and orientation toward mathematics and recognize the important role these understandings play in implementation of instruction, they often *design* mathematics instruction to reflect a more directive style. Reasons include difficulty of mathematics as a subject and wavering confidence in their developing mathematical orientations. Our continued research project will now follow these prospective teachers into their elementary mathematics methods course and student teaching experience. We anticipate that students will strengthen these tenuous connections as they experience teaching mathematics in more reform-oriented ways.

This study contributes to what is understood about prospective teachers' thinking concerning mathematics and its teaching and learning. Within this design experiment our shared vision of conceptually based mathematics education was able to be realized by collaboratively incorporating efforts early and connectedly in the teacher education process, thus stimulating interdisciplinary research in mathematics and elementary teacher education.

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